NATIONAL METALLURGICAL LABORATORY

ANNUAL REPORT

1957-1958

COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH

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JAMSHEDPUR, BIHAR, INDIA

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FOREWORD

I HAVE great pleasure in presenting the Report of the Director, National Metallurgical Laboratory for the year 1957-58.

The National Metallurgical Laboratory has now completed its seventh year of existence. Its research programme has been streamlined and is directed towards the discovery of effective uses of indigenous raw materials and development of substitute alloys to replace those imported at considerable expenditure of foreign exchange. Efforts in these and allied fields have been stepped up *pari passu* with the development of Indian metal industries under the powerful stimulus of the Five Year Plans of the Government of India.

From the material contained in the Annual Report, it will be observed that the main emphasis has been on attacking problems of direct development interest to the industry. It will also be noticed that, concurrently with such attack, research work on certain aspects of fundamental and basic metallurgical research has been energetically pursued. At present the research and development work is being directed towards the production of nickel-free austenitic stainless steel based on chromium-nitrogen-manganese-copper compositions, carbon-bonded graphite crucibles, development of mullite refractories, beneficiation of low-grade manganese ores, development of nickel-free high manganese coinage alloys, production of chromium-manganese alloys for incorporation in the nickel-free stainless steels, production of steel by the L.D. process utilizing indigenous dolomite and magnesite refractories. These activities have all a direct bearing on the development of mineral and metallurgical industries in the country. Significant results have already been reached in some of the industrial processes initiated at the National Metallurgical Laboratory on a laboratory scale, such as the production of electrolytic manganese metal, electrolytic manganese dioxide, concentration of low-grade manganese and other ores, production of special type of ferro-alloys, studies on soft and permanent magnet materials, beneficiation of low-grade manganese and chromite ores, production of refractories, which are now being translated to pilot plant scale. The process developed for the manufacture of carbon-bonded graphite crucibles has already been handed over to industries for commercial exploitation. The outcome of these projects, I am sure, will result in a sizable saving of foreign exchange and some of them may even earn foreign exchange for the country in the future. Due emphasis has also been laid on the studies of fundamental aspects of metallurgical problems, such as isothermal transformation characteristics of Indian steels, quench-ageing and strain-ageing embrittlement in steels, phase studies of electrodeposited alloys, preferred orientation in rolled sheets and studies of textures, structure of carbide in alloy steels, etc. etc. Collaborative investigations with the Indian Bureau of Mines, the Atomic Energy Establishment, the Metals Research Committee, the Railway Board, etc., have also been pursued.

In collaboration with the Metals Research Committee of the Council of Scientific & Industrial Research of which I have the privilege to be the Chairman, the National Metallurgical Laboratory is establishing one of the largest pilot plants anywhere and definitely the largest in India known, as the Low-shaft Furnace Project, at a cost of Rs. 27 lakhs capital and Rs. 10 lakhs recurring, to produce primarily commercial grades of pig iron, utilizing non-metallurgical coal or carbonized lignite, plentiful supplies of which are available in the country. The results obtained from this pilot plant should produce data of great value to the future development of iron and steel industry in India and will no doubt be watched with great interest by metallurgists and industrialists not only in India, but the world over.

Another significant contribution which the Laboratory has made in the dissemination of scientific knowledge to the industries is the holding of the demonstration of the technical 'know-how' of the four patented processes developed by the Laboratory, viz. electroplating on aluminium, chemical polishing on aluminium, brass plating from non-cyanide bath and metallization of non-conductors, which demonstration I had earlier the privilege of inaugurating before the representatives of small-scale industries. Even though the laboratory had received lump sum offers for the commercial exploitation of the above patented processes, I should commend the decision of the Laboratory to release the processes free of royalties, as the results of the investigations of this type find ready application in industry.

Early this year, this Laboratory arranged a successful symposium on "Recent Developments in Foundry Technology" and also an interesting exhibition, inaugurated by Prof. M. S. Thacker, Director-General, Scientific & Industrial Research. The National Metallurgical Laboratory has enjoyed at all times the support and goodwill of the Director-General of Council of Scientific & Industrial Research, Prof. M. S. Thacker, who has taken a keen personal interest in its affairs.

The National Metallurgical Laboratory is proceeding along right lines under the leadership of its Director Dr. B. R. Nijhawan and doing an extraordinarily good job of the different problems posed. There is tremendous work going on in the Laboratory having a direct bearing on the industry and related directly or indirectly to industrial growth during the Second Five Year Plan. I would like to take this opportunity to congratulate Dr. Nijhawan and his colleagues who are working hard in the pursuit of various research and development projects and have done commendable and excellent work. I feel sure that members of the Executive Council and others would like them to know that they deeply appreciate their painstaking endeavours as well as their sense of devotion to research.

J. J. GHANDY
Chairman
Executive Council of the
National Metallurgical Laboratory

Jamshedpur
8 December 1958

INTRODUCTION

The National Metallurgical Laboratory has passed through another eventful year of ceaseless activity. It has been a year of concerted efforts to tackle problems posed by the Second Five Year Plan. A dominant theme therein has been to investigate effectively and expeditiously the problem of replacement of non-indigenous elements and development of substitute alloys both in ferrous and non-ferrous fields. The National Metallurgical Laboratory has further endeavoured to consolidate its functions in respect of offering liberal facilities for technical assistance to the industry, small or big, and it is gratifying that it has registered an increase of several folds in these fields in terms of quantum of technical assistance rendered. The laboratory has now embarked upon the actual setting up of Pilot Plant Projects that had been in blue-print stages. During the last year, the pilot plant relating to Low-shaft Furnace Project has taken concrete shape and is expected to be in operation during the end of 1958. Concerted efforts have also been made to translate the results obtained on laboratory scale on to pilot plant stages. The fields thus enlarged relate to the development of nickel-free stainless steels, nickel-free coinage alloys, production of electrolytic manganese and manganese dioxide on a substantial scale. Steel, by oxygen injection technique, has been made for the first time in India even though on a pilot plant scale, in the L.D. oxygen converter at the National Metallurgical Laboratory. Semi-pilot plants for beneficiation of low-grade manganese went into operation treating almost a ton of ore per day. The pilot plants relating to aluminizing of steel wire and refractories, thermal beneficiation of ores, etc., are now also taking shape. Work on raw materials assessment for the new steel plants, studies on Salem iron ores concerning its beneficiation, reducibility and sintering characteristics have also been done.

The general themes of research and development actively underway in the National Metallurgical Laboratory embrace the following:

1. Development of rationalized ranges of alloy and special steels for production in India, mainly on the basis of indigenous alloy resources. The object is to develop new alloy steels which are not mere replicas of foreign standardized products but are based on indigenous alloying elements to meet the needs of Indian engineering and automobile industries.
2. Ore-dressing and mineral beneficiation of Indian ferrous ores together with non-metallic source materials like vermiculite, gypsum, graphite and sands for foundry purposes. Fundamental studies into flotation and properties of minerals.
3. Development of extractive metallurgical techniques based on fundamental thermodynamic theory — study of gaseous oxidation and reduction of mixtures and metallic reduction processes.
4. Extraction and utilization of rare metals whose ores occur in India (germanium, zirconium, beryllium, etc.).
5. Study of the properties of foundry-moulding sands, bonding materials and synthetic sand mixtures.
6. Protection by electroplating and allied processes.

DR. B. R. NIJHAWAN, DIRECTOR, EXPLAINING TO PRIME MINISTER, SHRI JAWAHARLAL NEHRU, VARIOUS PROCESSES AND PRODUCTS DEVELOPED AT THE NATIONAL METALLURGICAL LABORATORY, DURING THE LATTER'S VISIT ON 2 MARCH 1958. SIR J. J. GHANDY, CHAIRMAN, EXECUTIVE COUNCIL OF THE NATIONAL METALLURGICAL LABORATORY, IS SEEN ON THE PRIME MINISTER'S LEFT

7. Development and application of processes such as forging, rolling, wire drawing, etc., to the production on a small scale of material not at present produced in India and required for research, such as, clad aluminium alloys, thermocouple wires, etc. The mechanical working equipment will be received under Colombo Plan.
8. Development of alumino-silicate and silica refractories, carbon refractories, zircon refractories and other indigenous refractories and heat insulation materials from kyanite. Development of graphite crucible industry, etc.
9. Fundamental studies into isothermal transformation characteristics of Indian steels, heat-treatment cycles, grain-size control, etc., as also investigations into atomic X-ray structure of metals and alloys.
10. Development of new analytical methods including chemical, microchemical and physical.
11. Application of powder metallurgy techniques to different types of products. This is of special interest as it may lead to the development of small-scale methods of producing steel articles by direct reduction of ores in suitable moulds, in villages, on which good results have been achieved.

The Liaison and Information service has been enlarged considerably both in its scope and actual service rendered and is full of activity rendering useful service within and outside this laboratory.

The National Metallurgical Laboratory has continued to undertake collaborative research with other bodies, such as, Indian Bureau of Mines, Atomic Energy Establishment, Metals Research Committee, Railway Board, etc., by undertaking such projects as beneficiation of uranium ores, manganese and chrome ores, low-shaft furnace project, development of tinless bronzes, controlled friction materials, besides furnishing them with useful technical data. Besides, valuable contributions have been made to the Indian Standards Institution by the formulation of standard specifications on foundry sands, facing materials, methods of sampling foundry sands and manganese ores and methods of chemical analysis and also in the electroplating fields.

During the year under review, a symposium was also organized on "Recent Developments in Foundry Technology" in collaboration with the Institute of Indian Foundry Men, between 5th and 8th February 1958. An exhibition, depicting the present stage of the progress made by the Indian foundry industry, was also arranged for the first time in this country. The scope of the symposium covered the following subjects:

1. Raw materials for moulds and cores.
2. Materials and methods for fettling and handling of materials in the foundry.
3. Modern innovations in foundry technology like CO_2 process, shell-moulding.
4. New developments in melting including casting techniques and latest equipment.
5. Recent developments in the founding of ferrous and non-ferrous metals and alloys.

6. The position of foundry industry in India *vis-à-vis* Second Five Year Plan.
7. Foundry mechanization and layout.
8. Foundry management.

The symposium was international in character and was well attended by many distinguished scientists and technologists from India and abroad.

The symposium and exhibition were highly successful and should be regarded as one of the most important yet held in India, since the diverse subjects discussed had a direct bearing on the development and ultimate success of India's Second Five Year Plan which chiefly aims at the industrial expansion through the intensive development of light and heavy machinery and engineering industries.

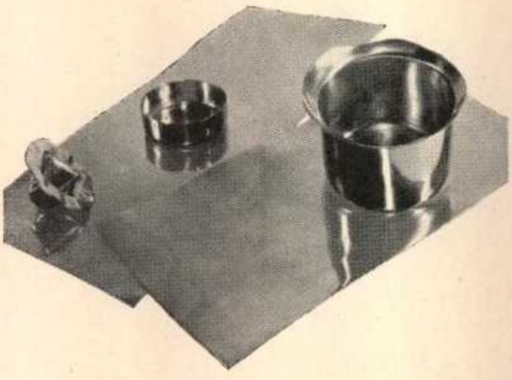
The Prime Minister, Shri Jawaharlal Nehru, visited the National Metallurgical Laboratory on 2 March 1958. He was accompanied by Dr. Zakir Hussain, Shri Morarji Desai, Sardar Swaran Singh, Shri J. R. D. Tata and Sir J. J. Ghandy. The Prime Minister and his party were shown different products and processes developed at the laboratory and the actual operations involved in the production of nickel-free stainless steels, electrolytic manganese and manganese dioxide, carbon and clay-bonded graphite crucibles, L.D. steel making and new nickel-free manganese based coinage alloys and coins.

The Prime Minister evinced keen interest in the work of the Laboratory and congratulated the Director and his staff on achievements of the Laboratory in different fields. The Prime Minister's visit came as a fitting climax to a year full of activity and all-round development in the multitude of functions of the National Metallurgical Laboratory.

RESEARCH PROJECTS

1.0 Nickel-free Austenitic Chromium-Nitrogen-Manganese-Copper Stainless Steels

Research and development work on nickel-free austenitic stainless steel based on chromium, nitrogen, manganese and copper has made significant progress. India possesses no resources of nickel and imports about 7000 tons of nickel-bearing austenitic stainless steel chiefly in the form of sheets annually, mostly for fabrication into utensils, etc. These substitute nickel-free stainless steels, developed in this laboratory, can successfully replace the 18 : 8 chromium-nickel steels in certain specific applications and hence their industrial production in India can save considerable foreign exchange. These substitute stainless steels have been made fully austenitic and non-ferro-magnetic despite their being wholly nickel-free, by virtue of their high optimum nitrogen content, an element readily available in nature. The structural, physical and corrosion resistance properties of these steels in different media have been comprehensively investigated at laboratories in India and in leading research organizations abroad. These steels possess excellent deep drawing properties consistent with high tensile strength and adequate ductility required for different fabrications such as utensils.



SOME TYPICAL STAINLESS STEEL ARTICLES FABRICATED FROM THE NICKEL-FREE STAINLESS STEEL

Comprehensive investigations has been made to determine the corrosion resistance of these steels in various media, such as vinegar ($42° \pm 1°C.$), lime juice water 1 per cent, sodium chloride ($41° \pm 1°C.$), 5 per cent citric acid with 1 per cent sodium chloride ($41° \pm 1°C.$), 5 per cent salt spray (ASTM B117-54T), 65 per cent boiling nitric acid (ASTM A 262-52T), 5 per cent boiling nitric acid and 5 per cent aerated sulphuric acid ($41° \pm 1°C.$). Simultaneous tests were carried out on 18 Cr: 8 Ni stainless steels in these media. These nickel-free stainless steels compared very favourably with 18 Cr: 8 Ni stainless steels except in the case of aerated sulphuric acid where their application is not recommended.

These nickel-free stainless steels can be used for utensils in Indian household including tumblers, thalis, katoris, spoons, pots, pressure cookers, cooking ranges, restaurant flat ware, etc. For wash-basins, lavatory pans and for similar other fittings on the Indian railway coaches these steels will prove equally useful. They may also be used for hospital wares, dairy equipment, decorative and architectural parts, steel furniture, high strength structural members, etc., and for applications requiring metals with low-magnetic permeability. These substitute steels can also be work-hardened to tremendous strength. In the cold-drawn state, these steels can develop ultimate strength of over hundreds of thousand pounds.

2.0 Study of the Properties of Indigenous Foundry Moulding Materials

Steady progress was maintained on this project which has been in progress since the last few years to assess the moulding characteristics of Indian foundry sand and determination of their suitability for various types of castings.

(a) Six sand samples collected from different places on the banks of river Brahmani from Sundergarh District in Orissa were investigated for Messrs Hindusthan Steel (P) Ltd., Rourkela, who are now exploring new sand deposits in close proximity to their steel plant. Test results have shown that these sands are not suitable for steel foundry purposes due to poor refractoriness.

(b) Adjoy River Sand, supplied by Messrs Chittaranjan Locomotive Works, was also investigated and it was observed that it could possibly be used for cast iron and non-ferrous foundry purposes.

(c) A sample of high silica sand supplied by Messrs Hargovindas Shivlal & Co., Bombay, on behalf of Messrs Mukand Iron & Steel Co., Bombay, was also studied. The sand grains were mostly medium coarse with a grain fineness number of 55. The sand possessed a high refractoriness, the fusion point being above 1680°C. and the sintering range of the sand was 1400° to 1450°C.

(d) Another high silica sand called Vengurla Sand supplied by Messrs Oriental Minerals at the instance of Messrs Mukand Iron & Steel Co. was investigated. With a silica content of 98 per cent and 1·72 per cent of alumina, it has a high fusion point (about 1680°C.) and fairly high sintering range.

(e) Besides, two natural moulding sands were also investigated. One of them, viz. Oyaria sand supplied by Messrs Chittaranjan Locomotive Works, assayed 78 per cent silica, 9 per cent alumina and 3 per cent iron oxide. A.F.S. fineness number of the sand was 47 and the sand fused at 1440°C. The grain shape was mostly sub-angular to round and the sand when used alone appeared to have a fairly wide moulding range and considered, therefore, suitable for cast iron founding. The sample of Damodar sand, obtained from Chittaranjan Locomotive Works, contained 19 to 24 per cent of clay grade matter and possessed a A.F.S. grain fineness number of 73. The grains were mostly sub-angular to round in shape and could be employed for cast iron and non-ferrous jobs.

Investigations on snow white silica sand, yellow moulding sand, parting sand and medium silica sand, supplied by Messrs Premier Automobile Co. Ltd., Bombay, are under progress.

2.1 *CO_2 Process*

Work on CO_2 process for the hardening of moulds and cores was pursued and the effect of moisture-free nitrogen compressed air and ammonia was studied for their hardening characteristics. Hardening was found taking place in all the cases. However, it was thought that a thorough understanding of the mechanism of hardening may prove more useful in further work on this process. In solution, sodium silicate can decompose to silicic acid which can then polymerize to silica gel but by whatever means the silica gel is formed, it is felt that the sand mixture develops high strength only after the gel is formed. Further investigations on the CO_2 process are under progress.

2.2 *Facing Materials*

An *ad hoc* study of the indigenous facing materials was also made at the instance of the Indian Standards Institution with reference to their suitability for practical foundry purposes, so that suitable specification could be formulated on the basis of the results obtained.

Samples of facing materials were obtained from

(a) Messrs Patna State Graphite Mining Co. Ltd.,

(b) Messrs Indian Iron & Steel Co. Ltd., Kulti,

(c) Messrs Hard Castle Waud & Co., and

(d) Messrs J. D. Jones & Co. Ltd.

All the samples were analysed for their proximate composition and tested in dry sand as well as green sand moulds for all possible foundry purposes. It was concluded that the graphite sample from Messrs Patna State Graphite Mining Co. could be utilized: (i) as a wet blacking when properly mixed with molasses and water to dry sand moulds for non-ferrous castings; (ii) as dry powder for dusting on the green sand mould surface for the production of light and medium iron castings; and (iii) as a dressing in metal moulds when mixed with kerosene oil and smoothened properly. The blacking sample supplied by IISCO (Kulti) was found to be quite promising for wet blacking when properly mixed with molasses and water. The Patna State Graphite Mining Co. and the Kulti blacking samples appeared to be quite satisfactory regarding their mechanical grading.

3.0 Aluminizing of Steel

During the period under review, work was concentrated on the organic flux process. Linseed oil, on account of its oxygen absorbing properties, was found suitable as organic flux in the hot-dip aluminizing of flux. Thickness of coating was controlled by striking a balance between temperature bath and dipping time. Alloying additions were made for control of coating thickness and improvement in ductility.

Panels aluminized from different baths were subjected to oxidation and salt-spray corrosion tests and satisfactory results have been obtained.

Aluminizing of Post and Telegraph Pole Hardware Stores was also undertaken with a good measure of success. Auto-muffler parts sent by Messrs Premier Automobile Ltd., Bombay, have been aluminized successfully.

4.0 Tinless Bronze

The chief difficulty encountered in the use of copper-lead alloys for bearing purposes is the seggregation of lead. A specific composition range within the ternary equilibrium diagram of Zn-Al-Cu was chosen as it appeared to satisfy the traditional structure of bearing alloys. The alloy was prepared and tested for wear loss and anti-frictional values and results showed that its anti-frictional property is superior to other types of bearing alloys, e.g. silicon-bronze, gun metal, leaded bronze and phosphor-bronze. In wear loss also it has been found superior to other alloys excepting silicon-bronze. Other tests such as fatigue and antiseizure tests are under way.

5.0 Powder Metallurgy—Porous Bronze Bearing

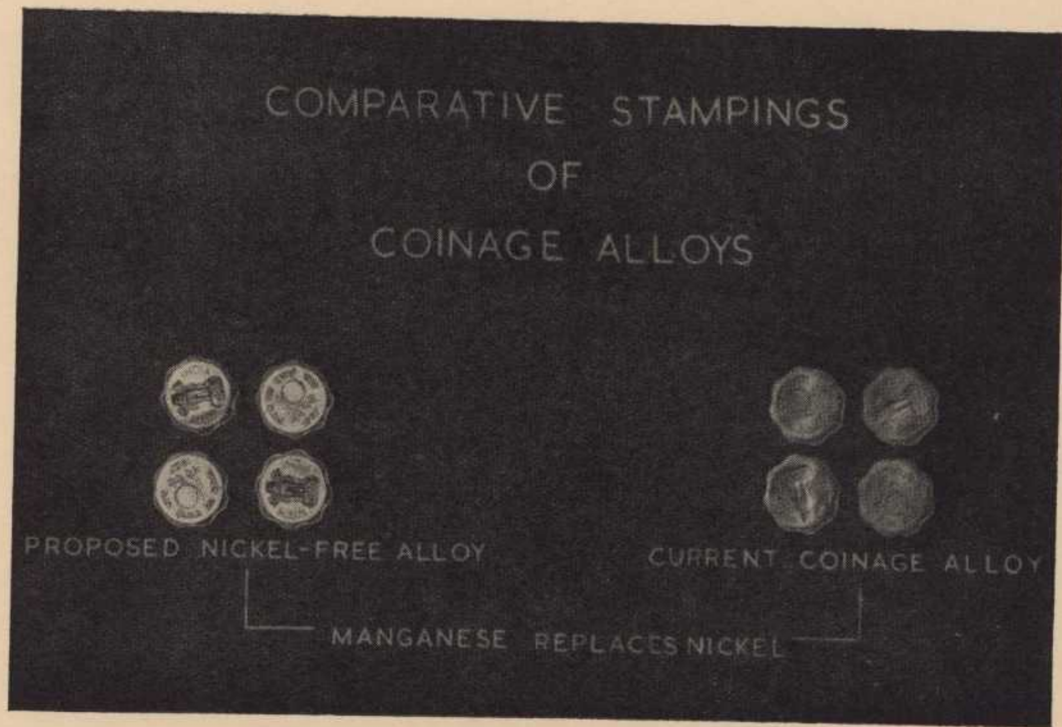
Experiments were continued on the study and evaluation of the properties and production of porous bronze bearings. Two types of bearings were made. One was self-aligning variety, such as those used in table fans and the other was a plain cylindrical bearing. Laboratory scale experiments on the manufacture of porous bearings as per standard commercial practice as well as further tests to evaluate and determine the conditions for obtaining bearings of required property were successfully completed.

6.0 Study of Isothermal Transformation Characteristics of Some Indian Steels

A dial gauge dilatometer has been set up to study the transformation characteristics of some selected Indian steels of slow transformation characteristics. The dilatometer was standardized by using two steels whose T-T-T curves are known. An apparatus is under fabrication where quenching will be done automatically.

7.0 A Study of Quench-ageing and Stain-ageing Embrittlement in Steels

This project was taken up with a view to study the possible causes, effect and prevention of quench and strain-ageing embrittle-



Coinage alloy developed at the National Metallurgical Laboratory

ment in steels. Five heats of Al-killed low-carbon steels were made to investigate the effect of aluminium on ageing and non-ageing properties of the steel. In one set of experiments two specimens were strained by reducing the diameter to the extent of 5 per cent. Its electrical conductivity, hardness and microstructure were studied. In another set of experiments the specimens were kept at 1100°C. in the furnace and hydrogen gas was passed for decarburizing. After 64 hours of treatment, the specimens were taken out and their microstructure and hardness were noted.

The nitrided decarburized specimen is being studied under X-ray.

8.0 Semi-Pilot Plant Production of Electrolytic Manganese Metal

The manganese plant was worked to the maximum limit of its capacity to meet the heavy demands for manganese metal in the multipronged alloy development programme of the National Metallurgical Laboratory. A number of well-established industrial and manufacturing firms have expressed their keen interest in the commercial exploitation of the process. The development of nickel-free stainless steel, coinage alloys and substituted brass have opened out new commercial outlet for electrolytic manganese.

The capacity of the plant will be increased to about 100 lb./day in the near future.

9.0 Development of High Manganese Coinage Alloy

Although nickel is an eminently suitable metal for coins, its shortage and absence of nickel ores in India pose a real problem in coinage production. Work has, therefore, been taken up to develop a suitable alloy containing manganese as one of the constituents which will be suitable as a coinage material.

Preliminary experiments have shown that alloys of three different nickel-free composi-
required in coinage metal containing nickel. In collaboration with Mint, coins were stamped out of these compositions which were found to be very satisfactory. Flow of metal in the die was good, the impression came out sharp and bright and the coin had a metallic ring. The three alloys are now under study for their corrosion and tarnish resistance.

10.0 Semi-Pilot Plant Production of Electrolytic Manganese Dioxide

The experimental cell designed and fabricated for production of manganese dioxide was run several times for about 10 to 15 days continuously. The deposited manganese dioxide after crushing, washing and drying, was found to contain about 90 per cent manganese dioxide and 10 per cent moisture, free from all impurities except for a very low percentage of graphite. Samples of manganese dioxide so obtained were sent to dry cell manufacturing firm for actual test in dry cells, results of which are awaited. In the meanwhile, arrangements have been made to carry out actual battery tests with electrolytic manganese dioxide.

Dry cell manufacturers are showing increasing interest in the product and a number of industrialists have enquired about the possibilities of manufacturing manganese dioxide on a large scale and negotiations are proceeding with them.

A 100 lb./day unit will be set up after the construction of the pilot plant bay, work on which has already commenced.

10.1 Preparation of Battery Active Manganese Dioxide from Low-grade Domestic Ore by Chemical Process

After initial crushing and grinding, the low-grade ore was reduced at 450°C. with a view to convert manganese to a soluble form and iron as insoluble Fe_3O_4. Leaching experiments were conducted with nitric
was possible to recover [illegible] per cent and it
acid which can be subsequently utilized for leaching. The decomposition of manganese nitrate was effected at 200°C. and manganese dioxide available oxygen as per cent MnO_2-89·5 was obtained. Further work is in progress.

11.0 Preparation of Electrolytic Chromium

A special type of electrolytic cells was devised to assure most efficient cooling of cathodes. The cathodes and anode chambers were kept separate by means of a porous diaphragm. Problems pertaining to stripping of the deposit was successfully overcome. Iron-chromium alloys of varying chromium content from 70 to 96 per cent chromium and ultimately metallic chromium of 98 per cent purity were obtained.

12.0 Studies on Atmospheric Corrosion of Various Metals and Alloys under Industrial Atmosphere

Various metals and alloys like mild steel, TISCOR, copper, brass, monel metal, stainless steel, etc., were exposed vertically and after different periods of exposure, their corrosion rates and surface conditions were studied. To determine the difference in corrosion rate with inclination of exposure, samples were exposed at 45°. Arrangements are being made to expose fresh set of samples in the summer season of the current year.

12.1 Studies on Corrosion Inhibitors

A comparative study of the efficiency of the anodic inhibitors, such as chromite, nitrate and phosphate were made on mild steel immersed in water for a period of three months and chromate was found to be the best inhibitor. A firm (Messrs Indian

Steel & Wire Products Ltd.), which was experiencing difficulty due to corrosion of some parts of their air-conditioning plant, was advised to use this inhibitor at optimum concentration in their tests and this has practically stopped the corrosion.

13.0 Production of Magnesium by Electrolytic Method from Magnesium Chloride

Messrs Tata Chemicals, Mithapur, produce large quantity of magnesium chloride as a byproduct in their salt industries, which has a very limited market. Attempts are being made to produce magnesium metal from this byproduct which will find considerable use in defence services, and also for producing light metal alloys.

As a first step in the production of magnesium, about 20 lb. of dried magnesium chloride was prepared for electrolysis and a small electrolytic cell complete with ceramic diaphragm and electrodes has been designed and fabricated.

14.0 Preparation of Liquid Gold

Almost the entire demand for liquid gold in India is met by import. The present work was taken up to develop a simpler method for production of liquid gold comparable to imported variety. With gold bullion and other materials, mostly indigenous, liquid gold of proper quality has been produced which yielded highly satisfactory results when tested on glass and ceramic surfaces, in respect of colour, adherence and texture.

15.0 Electroplating on Aluminium and Its Alloys

This investigation was taken up with a view to evolve the details for a successful commercial process for plating of nickel, chromium, gold and silver, etc., on aluminium and its alloys. Two new processes on plating on aluminium were developed and patented and the method was worked successfully on a fairly big scale in the laboratory.

Experiments carried out on the plating of aluminium-silicon alloys (containing 5 to 13 per cent silicon) showed that with some modifications in the pretreatments it is possible to plate Al-Si alloy containing up to 5 per cent silicon. However, higher percentage of silicon introduces certain difficulties as regards adhesion, and experiments are in progress to overcome these difficulties.

15.1 Brass Plating from Non-cyanide Bath

A series of experiments were carried out on the electrodeposition of brass at constant cathode potentials from non-cyanide electrolyte containing different concentration of copper and zinc. It was observed that the percentage of copper in the deposit decreases with the decrease of cathode potentials. Structure of the deposited brasses were analysed by X-ray diffraction.

The large-scale experimental trial on brass-plating from non-cyanide bath has indicated the possibility of utilizing this process for commercial practice. The process developed in this laboratory has since been released free of royalty to all interested parties.

15.2 Deposition of Copper on Mild Steel Wire by Immersion

There is a great demand for chemically copper-coated mild steel wire in the market. The coating should be firmly adherent and should stay even after redrawing of the coated wire. In the absence of suitable method for this purpose work was taken up to develop a suitable bath and a method to coat mild steel wire with copper by immersion in copper salt solution.

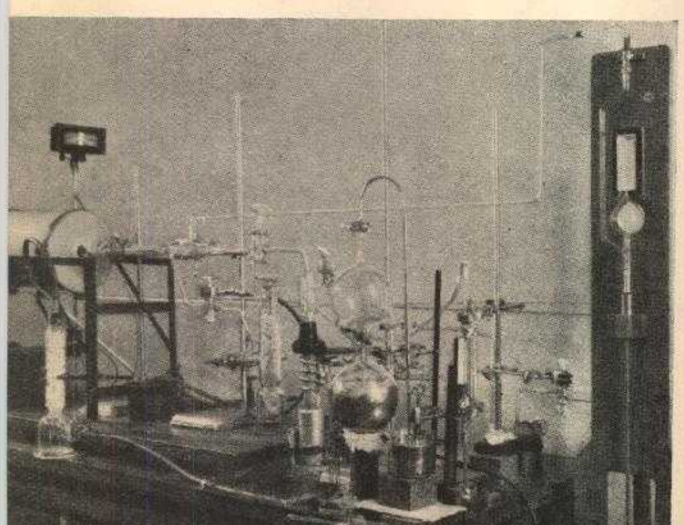
A large number of experiments were carried out to evolve a suitable bath for depositing copper without the use of acetrol or other imported proprietory products which are used at present. It was found possible to deposit copper by immersion from a copper bath containing indigenous raw materials. This copper bath gives smooth, bright and adherent copper deposits on the mild steel wire by immersion. Work on further improvement of the bath is continued.

15.3 Phase Studies on Electrodeposited Alloys

Electrodeposited Ni-Zn alloys with varying proportions of nickel and zinc provides a very interesting field for the study of the phase transformation. Study of the effect of annealing on the phase transformation of electrodeposited alloy can be expected to furnish useful link between phase patterns of electrodeposited and thermal alloys. Besides the above theoretical interest, the electrodeposited Ni-Zn alloys are known to provide corrosion resistant and bright finish on base metal surfaces.

Forty compositions of fresh alloy deposits were made and conditions for their deposition studied. X-ray patterns of these alloys were also studied. It was noticed that all the phases could be found in electrodeposited alloys. Annealing shows a tendency for the phase patterns to shift towards equilibrium structure.

Hydrogen determination apparatus — designed and fabricated at the National Metallurgical Laboratory



The influence of pH, agitation and boric acid on the composition of Ni-Fe alloy deposits was also studied. Study of the structure of deposits obtained at constant cathode potential is under progress along with detailed investigation on the properties of nickel-zinc alloys.

16.0 Determination of Hydrogen in Metals

The presence of gases in metals is known to influence their properties and at times rather adversely. There has been, therefore, persistent efforts from the analytical side to develop accurate and convenient method for the determination of gases in metal and in order to make such facilities available in N.M.L. for their estimation, work was undertaken to set up

(i) an apparatus for determination of hydrogen, and
(ii) an apparatus for determination of gas by vacuum fusion method in metals.

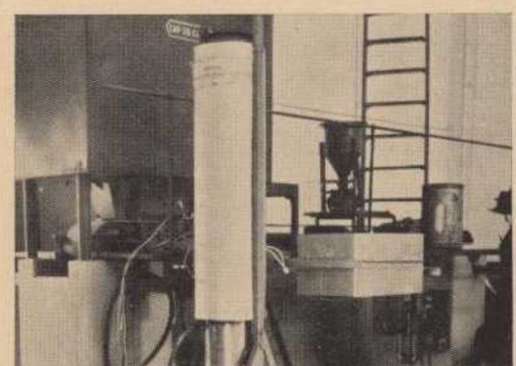
An apparatus with all the necessary accessories has been fabricated in this laboratory for the determination of hydrogen in steel and ferro-alloys. The hydrogen content of various low-alloy steel, manganese, stainless steel and carbon-free ferro-chrome have been estimated by this apparatus and the values obtained are quite reproducible. By assembling this apparatus foreign exchange worth about Rs. 10,000 has been saved.

16.1 Vacuum Fusion Apparatus for Estimation of Gases in Metals

A ready-made assembly of this apparatus costs foreign exchange worth about Rs. 60,000. Under the present economic position it was decided to save the major part of the foreign exchange by fabricating the apparatus in the laboratory. Work on setting up the apparatus is under progress.

17.0 Semi-Pilot Plant Studies on the Beneficiation of Ferruginous Manganese Ore from Keonjhar Dist., Orissa, Based on Low-temperature Reduction Process

A low-grade ferruginous manganese ore from Keonjhar District, Orissa, received from Messrs Tata Iron & Steel Co. Ltd., was studied on a semi-pilot plant scale based on low-temperature magnetizing reduction roast. The sample assayed Mn 27·2, Fe 24·2, SiO_2 7.53, Al_2O_3 7·43 and P 0·09 per cent and could be upgraded economically by washing and low-temperature magnetizing reduction process followed by magnetic separation to yield a manganese concentrate of grade 51·7 per cent Mn with a Mn to Fe ratio of 7 : 1, $SiO_2 + Al_2O_3$ less than 12 per cent and P 0·11 per cent with a recovery of 62·0 per cent Mn. The ratio of concentration was 3·0. Magnetic iron concentrate obtained during this process can be employed for producing spiegel or for charging into the blast furnace as a source of manganese in pig iron. The process is developed in such a way that it does not need external heat for the reduction roast, and it yields a friable product which can be crushed very easily for the subsequent operations.



VERTICAL REDUCTION FURNACE — DESIGNED AND FABRICATED AT THE NATIONAL METALLURGICAL LABORATORY, FOR TREATING FERRUGINOUS MANGANESE ORE

On the basis of the results obtained during a large number of experiments conducted on a laboratory as well as semi-pilot plant scale, a flow sheet was developed for a plant to treat 600 tons of ore per day required to produce 30,000 tons of standard grade ferro-manganese at Joda. Machinery required for this plant as well as costs have been worked out.

17.1 Pilot Plant Studies on the Beneficiation of Ferruginous Manganese Ore by the N.M.L. Patented Process

The sample of ferruginous manganese ore from Orissa received from Messrs TISCO was investigated on a pilot plant scale by reduction roast followed by magnetic separation methods. Pilot plant scale studies on the ferruginous ores employing the patented process, developed at the National Metallurgical Laboratory, are under progress. Heating of the manganese-rich fraction assaying 34·73 per cent Mn and 20·5 per cent Fe to 400°C. for one hour, followed by magnetic separation, produced a magnetic fraction (manganese concentrate) assaying 45·94 per cent Mn and 12·78 per cent Fe but with a recovery of only 36 per cent Mn in the product. Further work to improve the grade of concentrate and manganese recovery is in progress.

17.2 Beneficiation of Low-grade Manganese Ore

(i) *From Kumsi, Mysore* — The original sample assayed 34·4 per cent Mn, 4·5 per cent Fe, 30·34 per cent SiO_2, 3 per cent Al_2O_3 and 0·072 per cent P. Magnetic separation at −65 mesh after desliming yielded

HORIZONTAL REDUCTION FURNACE — DESIGNED AND FABRICATED AT THE NATIONAL METALLURGICAL LABORATORY, FOR TREATING FERRUGINOUS MANGANESE ORE

a manganese concentrate assaying 48·0 per cent Mn, 4·64 per cent SiO_2 with a recovery of 67·1 per cent Mn. Flotation tests to float pyrolusite are in progress.

(ii) *From Sambalpur, Orissa* — A low-grade manganese ore received for beneficiation tests from Rairakhol Mines in Sambalpur, Orissa, assayed Mn 38·53 per cent, MnO_2 52·20 per cent, Fe 17·5, SiO_2 3·38, Al_2O_3 5·02, BaO 4·03 and P 0·35 per cent. Reduction roast of original sample followed by magnetic separation at different sizes produced manganese concentrates assaying 53·0, 55·2 and 54·0 per cent Mn with manganese recoveries of 71·0, 81·0 and 82·0 per cent at −10, −35 and −65 mesh sizes respectively for a Mn/Fe ratio of 7 to 1. But the phosphorus in the concentrate was high, viz. 0·34 per cent. Fatty acid flotation was not successful in producing a low-phosphorus manganese concentrate.

(iii) *From Chitaldrug, Mysore* — A low-grade ferruginous manganese ore from Chitaldrug, Mysore, assayed Mn 32·51, Fe 20·59, $SiO_2 + Al_2O_3$ 10·83 and P 0·085 per cent.

Reduction roast of unwashed ore at −3 mesh followed by magnetic separation at −48 mesh gave a manganese concentrate assaying 53·69 per cent Mn (Mn/Fe ratio 7 : 1) with a recovery of 48·3 per cent Mn. The grade of concentrate for a Mn/Fe ratio 7 : 1 improved to 54·4 per cent manganese for a recovery of 52 per cent when washed ore was used for reduction roast and magnetic separation of the reduced ore performed at −48 mesh.

(iv) *From Kodur Mine Dumps, Andhra* — Beneficiation studies of a low-grade manganese ore from the dumps at Kodur, analysing Mn 24·3, Fe 12·9, SiO_2 17·9, Al_2O_3 10·5 and P 0·26 per cent showed that reduction roast of the gravity concentrate followed by magnetic separation can yield a concentrate assaying Mn 46·3, Fe 6·2 and P 0·21 per cent with a manganese recovery of 55·6 per cent.

Concentrate obtained was, however, too high in phosphorus for making standard grade ferro-manganese.

(v) *From Kuttinga, Koraput Dist., Orissa*— A low-grade manganese ore from Kuttinga in Koraput District, Orissa, received from Messrs Jeypore Mining Syndicate, assayed Mn 38·9, Fe 10·7, SiO_2 7·8, Al_2O_3 4·9 and phosphorus 0·35 per cent. Reduction roast followed by magnetic separation at −10 mesh yielded a manganese concentrate assaying Mn 50·8 and Fe 6·2 per cent with a recovery of 94·1 per cent Mn.

18.0 Beneficiation of Low-grade Iron Ores

(i) *Low-grade Magnetite from Salem, Madras* — Beneficiation studies were conducted on a magnetite ore assaying Fe 36·5 and SiO_2 44·2 per cent. Dry magnetic separation at −10 mesh followed by wet magnetic separation of the rougher concentrate at −48 mesh produced a final concentrate assaying Fe 61·98 and SiO_2 12·1 per cent with a recovery of 86·5 per cent Fe.

Tabling the sample at −48 mesh gave a concentrate assaying Fe 65·21 and SiO_2 8·8 per cent with an overall recovery of 82·8 per cent Fe. Pilot plant tests were also conducted employing tabling as well as magnetic separation.

(ii) *Sintering Studies on the Magnetic Concentrate Produced from Low-grade Salem Magnetite Ore* — Systematic work on the sintering of the concentrate obtained from Salem magnetite ore has been taken up and after a few trials a satisfactory sinter was obtained. Further work is in progress.

(iii) *Iron Ore Samples from Bonai, Orissa* — A sample of iron ore from Bonai, Orissa, was received from the Indian Bureau of Mines at the instance of the Ministry of Steel, Mines and Fuel, Government of India, with a request to upgrade the sample to about 65 per cent Fe, in connection with the export of iron ore to Japan. The sample assayed Fe 59·6, SiO_2 2·23 and Al_2O_3 4·45 per cent and loss on ignition at 1000°C. 7·5 per cent. Calcining the sample at 500°C. and above eliminated most of the combined water, thereby automatically upgrading it to over 64 per cent Fe. The saving in freight for the calcined enriched ore, it is felt, should more than offset the cost of crushing and calcining.

(iv) *Beneficiation of Low-grade Iron Ore from Badampahar* — A sample of iron ore from Badampahar Mines of TISCO was received for removal of impurities such as silica and alumina. The ore assaying Fe 54·11, SiO_2 6·47, Al_2O_3 4·92, Mn 1·06 and loss on ignition (at 800°C.) 8·54 per cent was treated and a concentrate assaying Fe 61·31, SiO_2 2·63, Al_2O_3 1·81 and loss on ignition 7·13 per cent was produced by tabling followed by magnetic separation.

19.0 Beneficiation of Low-grade Kyanite

(i) *From Badia, Bihar* — A sample of low-grade kyanite from Badia, Bihar, received from Messrs Natural Sciences, India (Private) Ltd., assayed Al_2O_3 45·34, SiO_2 49·37, Fe_2O_3 0·53, TiO_2 0·47, CaO 1·00, MgO 0·38, Na_2O and K_2O 1·68 per cent and traces of sulphur. Flotation employing sodium sulphonate and lactic acid at a *p*H of 3 yielded a concentrate assaying 60·23 per cent Al_2O_3 with a recovery of 78·5 per cent Al_2O_3.

(ii) *From Singhpura, Bihar* — Another sample of low-grade kyanite was also received from Messrs Natural Sciences, India (Private) Ltd., for beneficiation. The sample assayed Al_2O_3 51·23, SiO_2 43·2, Fe_2O_3 0·7, TiO_2 1·38, MgO 0·56, CaO 0·43 and alkalies 1·03 per cent. A concentrate assaying over 60 per cent Al_2O_3 was required to be produced. Flotation employing sodium sulphonate and lactic acid produced a concentrate assaying 61·1 per cent Al_2O_3 with a recovery of 82·7 per cent Al_2O_2 present in the sample.

20.0 Beneficiation of Fluorspar

(i) *From Bhagatwali Mine, Rajasthan* — A sample of fluorspar was received from the Director of Mines and Geology, Government of Rajasthan, for beneficiation tests. The sample assayed CaF_2 56·48, SiO_2 34·7, $CaCO_3$ 3·58, Pb 0·29, Al_2O_3 2·4 and Fe_2O_3 0·96 per cent. Flotation produced a concentrate assaying 87·78 per cent CaF_2 with a recovery of 90 per cent CaF_2 in the product. Further work to improve recovery is in progress.

(ii) *From Ramorwali Mine, Rajasthan* — This sample received also from the Director of Mines and Geology, Government of Rajasthan, assayed CaF_2 21·14, SiO_2 52·35, Fe_2O_3 0·76, S 0·12, Pb 0·31, Al_2O_3 10·02 and $CaCO_3$ 2·1 per cent. Flotation tests produced a concentrate assaying 83·3 per cent CaF_2 with a recovery of 83 per cent in the product. The flotation concentrate was found to be high in Pb (1·24 per cent) and hence in the subsequent flotation tests Galena was floated first employing K-Ethyl Xanthate and cresylic acid and then the fluorspar was floated using fatty acid. Further work is in progress.

21.0 Beneficiation of Gypsum Sample from Rajasthan

Four samples of low-grade gypsum received from Messrs Bikaner Gypsum Ltd., Bikaner, assayed SO_3 32·84, 37·15, 38·55 and 36·58 per cent with gypsum equivalents of 70·62, 79·87, 82·88 and 78·59 per cent respectively. Flotation performed with −150 mesh rejected fractions using sodium oleate yielded concentrates assaying SO_3 45·51, 45·55, 45·81 and 45·06 per cent with recoveries of 70·1, 83·1, 83·5 and 66·3 per cent respectively of the flotation feeds. The 150 mesh fraction met the specification required for fertilizer production and the flotation concentrate could also be used for plaster of paris.

22.0 Reduction of Silica Content in a Magnesite Sample from Salem

A sample of magnesite assaying MgO 44·51, SiO_2 2·85, Fe_2O_3 0·33, Al_2O_3 0·41, CO_2 48·76, CaO 0·6 and loss on ignition at 350°C., 1·73 per cent was obtained from Messrs Tata Iron & Steel Co. Ltd. and Messrs Kricher and Benner of Didiers to investigate whether the silica content could be brought to less than 1·5 per cent. Heavy media separation at sp. gr. 2·65 followed by flotation of the heavy media reject after grinding, produced an overall recovery of 71·8 per cent by weight of magnesite concentrate assaying 1·28 per cent SiO_2.

23.0 Preliminary Report on the Possibility of Beneficiating a Sand Sample from the Associated Cement Companies

A sand sample was received from Messrs Associated Cement Companies Ltd., Bombay, for a preliminary investigation to see whether it can be beneficiated to make it suitable for production of Portland cement. Elimination of 30 per cent by weight of quartz alone from the sample by fatty acid flotation would yield a product suitable for Portland cement manufacture but this may not be possible in practice.

24.0 Study of Indian Refractory Clays

A comprehensive study has been taken up on determining the properties and the possibilities of improving the quality of refractory clays and work was completed on thirty-two different types, which formed the first batch investigated so far. The entire work has been reported in three parts — the first part comprises of clays from Madhya Pradesh, the second on clays from Bihar, Bengal and Orissa and the third on clays from Mysore.

Work was also done on the possibility of improving the low-temperature properties of the clays by *p*H control. It was found that many of the clays studied were amenable to such treatment.

25.0 Development of High Alumina Refractories from Indigenous Bauxite

(i) *Shevaroy Bauxite* — Suitable composition, grading, forming and firing techniques were developed for the production of 70 per cent alumina bricks using Shevaroy white bauxite. The product developed has good physical properties, like refractoriness under-load, spalling resistance and slag resistance, etc., by virtue of its high mullite content. A few full size bricks were produced and pilot plant trials will be taken up as soon as the necessary equipment are installed. Similar work on the development of 80 per cent alumina bricks using Shevaroy bauxite is being taken up. These high alumina refractories meet a variety of service requirements in metallurgical furnaces, cement kiln and boiler installations.

(ii) *Lohardaga Bauxite* — A sample of Lohardaga bauxite which is high in titania was supplied by the Orissa Cement Co. to investigate the possibility of its use for refractory purposes. Preliminary experiments carried out with the bauxite mixed with Belpahar non-plastic clay have yielded very encouraging results as regards the use of Lohardaga bauxite for the production of bricks with 70 per cent Al_2O_3.

26.0 Studies on Quartzites with a view to Develop Super-duty Silica Bricks

The inversion characteristics of ten samples of quartzites collected from different localities were studied. One sample of quartzite from Jamda area which was of the chalcedonic variety gave very encouraging result as a suitable raw material for super-duty silica brick. Further work is in progress to improve the porosity of the product developed from Jamda quartzite as well as from silica stone.

27.0 Production of Basic and Special Refractories from Indigenous Sources

(i) *Magnesite Refractories from Almora Magnesite* — Based on a detailed study of the mineralogical and chemical constitution as well as physical and refractory properties of the Almora magnesite from Doba area, a process for the manufacture of magnesite bricks was evolved. These bricks possess excellent refractory properties comparable to the indigenous or foreign products.

The unique advantage of the Almora magnesite over the South Indian magnesites lies in the fact that no sintering medium needs to be added. The increased requirements of magnesite refractories and the proximity of this deposit to the existing and new steel plants, present great scope for its commercial exploitation.

(ii) *Production of Chrome-magnesite Refractories* — With a view to utilize the chrome ores for chrome-magnesite refractories, ores from Orissa, Bihar and Mysore are being studied. Investigations on Orissa ore was taken up in the first instance and chrome-magnesite bricks made from these ores have given encouraging results. The properties studied so far relate to mineralogical and chemical constitution, the influence of the grain size, and magnesite content on the properties, such as bulk density, spalling resistance, bursting expansion tendency, refractoriness underload and slag resistance.

(iii) *Studies on Dolomites* — Stabilized dolomite is cheaper than the magnesite refractory and can be used in place such as sub-hearths and side walls on open hearth and electric furnace. It is also an excellent refractory for basic cupola. A suitable process was, therefore, evolved for the stabilization of Indian dolomite and for manufacturing refractories from the stabilized product. A patent on this subject has since been filed.

(iv) *Sintering and Semi-stabilization of Bhilai Dolomite* — Optimum conditions for the sintering and semi-stablization of Bhilai dolomite were determined at the request of the Bhilai Steel Plant authorities. Properties, such as crushing strength, grain size and mineral constitution were also determined. The clinkered dolomite could be stored safely for four weeks without perishing and can be used for fettling the open-hearth furnaces and basic converters.

(v) *Tar Bonding and Semi-stabilization of Dolomite* — Tar-bonded semi-stable dolomite is widely employed for lining in L.D. converters. Optimum conditions for tar binding, such as viscosity and water content of tar, temperature of mixing grain size of the burnt dolomite, etc., are being worked out.

(vi) *Utilization of Low-grade Chrome Ores for Production of Refractories* — Large deposits of low-grade chrome ores are available in Salem District, Madras. As the ore is highly siliceous, ferruginous and aluminous, it has not been found suitable for use in the as mined state. With a view to utilize the ore for refractory purposes, preliminary studies have been made and this has shown that the ore can be made refractory by suitable additions. Further work is in progress.

(vii) *Development of Plastic Chrome Ore or Chrome Plastic* — Plastic chrome ore is widely used in India for lining the soda-recovery furnace in paper mills. Being at present imported, it involves expenditure of considerable amount of foreign exchange. This investigation was taken up at the request of the Ministry of Commerce and Industry which enquired about the feasibility of its manufacture in India from indigenous raw materials. A suitable composition was, therefore, developed having good air setting and refractory properties and 100 lb. of it has been sent to Titaghur Paper Mills for practical trial.

(viii) *Refractory Composition Consisting of Graphite and Silicon Carbide* — Crucibles of 28 lb. capacity were subjected to a series of service tests with highly corrosive melts and full-scale service trials on these compositions have been completed. A number of leading firms have come forward to undertake the manufacture of these crucibles on a commercial scale and it is hoped that very soon this patented process will be released for exploitation in the private sector.

(ix) *Refractory Composition Consisting of Clay and Graphite* — Experimental work on the various aspects of this problem were successfully completed. After an extensive series of trials, a number of clay graphite bodies based on indigenous raw materials were perfected and glaze compositions suitable for rendering these bodies oxidation resistant were also investigated. The most promising composition of these bodies and glazes are the subject matter of a patent application filed during the year. Further work is now in progress on improving these compositions.

(x) *Study on Graphites* — Though graphite is a vital raw material for graphite crucibles and much research has been done on its crystallography and other fundamental characteristics, no suitable methods have yet been devised for comparing graphites from various natural sources from the point of their utility in crucible industry. Specification for crucible grade graphite available in countries like U.K. and U.S.A. appear to be mostly empirical and stipulate only particle size of the material and its carbon content. It was with a view to devise method for comparison of graphites that this work was taken up. As a first step, oxidation of a number of graphites were studied and the order as well as course of the reaction was determined. This has yielded interesting data and awaits further work before the suitability of this test as a standard test for graphites can be assessed. On the other side, the American and U.K. specifications are being reviewed critically. A number of tests have been planned to study the scientific basis for these specifications. This aspect of the problem is of great importance to the graphite mining industry in India as none of the graphites now marketed as crucible grade in this country could pass the grade, if U.K. or U.S.A. specifications are adopted.

PRODUCTION OF GRAPHITE CRUCIBLES ON A PILOT PLANT SCALE IN THE NATIONAL METALLURGICAL LABORATORY

(xi) *Zircon Refractories* — A systematic study on the utilization of zircon concentrate from the monazite-bearing beach sands of Travancore was pursued with the object of developing zircon refractories suitable for use in the furnaces for melting aluminium etc. The two important aspects are (i) selection of suitable additions and optimum firing temperatures for the production of dense grog from raw zircon sand and (ii) utilization of this dense grog along with ball mill fines and raw zircon sand in the correct proportions for development of a dense refractory that can stand severe corrosion by molten metals at commercially feasible temperatures. Results so far obtained have indicated that it would be possible to manufacture zircon refractories having properties comparable to foreign products.

(xii) *Development of Calcium-aluminate Cements* — After a thorough preliminary study of the factors involved, two calcium aluminate cement compositions were developed using Bisra limestone and Shevaroy ferruginous bauxite in one and Shevaroy red bauxite in the other. Larger batches were melted in an electric arc furnace and the resulting clinker was crushed and ground and mixed with graded fire clay grog in different proportions. Dry pressed, rammed or cast specimens produced from these mixes showed very good physical properties comparable to imported " Cement Fondu ".

28.0 Development of Permanent Magnet Materials

There is practically no commercial production in India of permanent magnet materials and the entire requirements of the country are at the moment being obtained from abroad. Work was, therefore, taken up on the development of permanent magnetic materials, with a view to meet ultimately the demand of the country from internal production. Investigations have been initiated in the first instance on the preparation and study of the alloys of the well-known Alni and Alnico types; development of permanent magnets from wholly indigenous materials will be taken up at a latter stage.

The study of the magnetic properties of the permanent magnet materials is being carried out by the ballistic method and an elaborate experimental arrangement has been set up, which includes a water-cooled solenoid capable of producing over an appreciable length (about 8 in.) a uniform magnetic field of as much as about 3000 oersteds. A number of alloys of the Alni and Alnico types have been prepared and their magnetic properties and heat treatment schedule have been exhaustively studied in both the as cast and heat-treated conditions. Further work is in progress to arrive at the optimum heat treatment schedule.

29.0 Electrical and Magnetic Properties of Some Low-Manganese, Low-Aluminium Steels

Work has been taken up to develop low-manganese, low-aluminium steels suitable for use as a core material in transformers and electrical machines, with a view to improve upon, if possible, the conventional 4 per cent silicon steel sheets now generally used.

About a dozen steels with the composition of aluminium and manganese, each ranging in the range 0 to 5 per cent, were investigated and the full range of magnetic properties determined. The rolling characteristics of some of these steels have also been studied. as ultimately these steels will largely be used as sheet. More work is in progress.

30.0 Preferred Orientation in Rolled Sheets

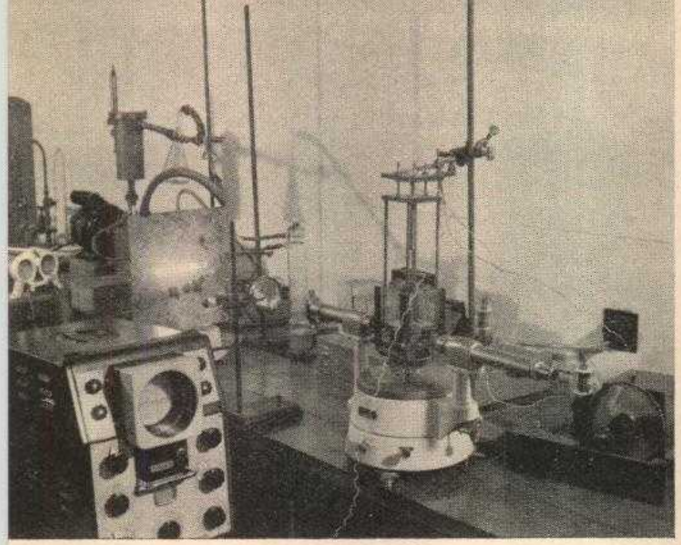
The usual method of determining the preferred orientation produced on cold rolling sheets is based on the study of the nature and intensity of X-ray reflections. This method could advantageously be replaced, if possible, by methods based on the values of the electrical conductivity and the velocity of propagation of stress waves in rolled sheet as a function of direction.

As a preliminary and also to first obtain quantitatively the extent of preferred orientation present in cold rolled sheets the standard methods using X-rays were followed and during the period under review, the preferred orientation in cold rolled aluminium sheet was exhaustively studied for various rolling procedures.

In the course of this study, an interesting method for evaluating the absorption of X-rays after scattering by the metallic sheet itself has been developed.

30.1 Mechanical Properties of Stressed Materials

The object of this investigation is to study by resonance methods the velocity of propagation of acoustic waves of medium to high frequency in previously stressed test pieces, to examine whether changes in the mechanical properties arise and can be determined. With the same experimental set-up, it will also be possible to study the



EXPERIMENTAL SET-UP FOR THE DETERMINATION OF ELASTIC CONSTANTS OF METALS BY ULTRASONIC EXCITATION

elastic constants of various dilute alloys, besides several physical transformations taking place in alloys at room and elevated temperatures. These studies are of great value in obtaining a clear picture of the nature of the forces of cohesion in metallic alloys.

During the year under review, an experimental set-up for carrying out this investigations has been mostly fabricated in the laboratory, and trial experiments started.

31.0 Structure of Carbide in Alloy Steels

Considerable progress was made in this investigation on the influence of heat treatment as well as relative alloy contents upon the nature and structure of carbides in alloy steels. The method for the extraction of carbide particles, by impinging upon a mildly electrolytically pickled specimen, an ultrasonic beam of moderate frequency and high intensity was modified and carefully standardized so that small quantities of precipitates can be suitably extracted. It was possible, during this method, to extract enough carbide as to permit an accurate chemical analysis to be carried out for the major elements present in the carbide. X-ray investigations were carried out on a number of carbides extracted from two chromium steels having 5 per cent chromium and 0·8 and 0·35 per cent carbon respectively, after various isothermal transformation treatments. The results of X-ray analysis indicated that for moderate soaking periods, the carbide corresponding to the composition Cr_7C_3 is generally obtained. Further work is in progress.

32.0 Lattice Parameters of Iron-chromium Alloys and Study of the Sigma Phase in Alloy Steels

Work has been taken up with a view to determine the nature and structure of the sigma phase arising in alloy systems of the transition elements. The importance of this investigation can be appreciated from the fact that the presence of sigma phase generally renders steel unsuitable for fabrication and cold deformation. The lattice parameters of iron-chromium alloys have also been shown to vary in a somewhat unexpected fashion and an accurate study of these lattice parameters of iron-chromium alloys can also throw light on certain fundamental aspects of alloy formation, such as short range order, existence of Brillouin zone overlaps, stacking faults, etc., besides helping in the clarification of a recent report that ageing takes place in iron-chromium alloys.

The design of an argon arc furnace for making very pure alloys has been completed and a vacuum annealing furnace for homogenization of these alloys is being fabricated. In these investigations, it is proposed to make very pure alloys, homogenize them in vacuum and measure accurately their lattice parameters, after suitable heat treatment, both at room temperature as well as elevated temperature.

33.0 Utilization of Vanadium-bearing Titaniferrous Magnetite Deposits of Singhbhum and Mayurbhanj

The vanadium-bearing deposits in India are located at Singhbhum and Mayurbhanj districts and contain about 1·5 to 2·5 per cent vanadium pentoxide with 10 to 16 per cent titanium dioxide. The reserves are estimated to be about 20 to 22 million tons. Investigations have, therefore, been taken up for the recovery of vanadium by (i) salt roasting and (ii) chlorination, for the utilization of these deposits for the production of vanadium pentoxide and subsequently ferro-vanadium.

(i) *Salt Roasting* — A systematic study of the roasting of the ore with sodium salts has indicated that it is possible to leach about 76 per cent of the vanadium from the ore using 20 per cent sodium carbonate for roasting. No marked recovery was observed on increasing the sodium carbonate content to more than 20 per cent. The roasted mass was leached with water and the leaching at different temperatures has indicated that a minimum of 70°C. is desirable for maximum recoveries.

A small unit for continuous work will soon be set up for working out the details for the pilot plant.

(ii) *Chlorination*—Preliminary experiments carried out at 150°, 200°, 250° and 300°C. for various periods ranging from 30 min. to 2 hr. indicated that 80 to 90 per cent vanadium could be recovered at 150° to 200°C. It is proposed to carry the reaction with the mixture of chlorinating agent and hydrogen gas to supress the chlorination of iron and also to study the effect of particle size, binders and fluidized bed.

34.0 Production of Iron-chromium-Manganese Alloys by Alumino-Thermic Reduction

Work has been taken up to produce Fe-Cr-Mn alloy of suitable composition to be utilized in the production of nickel-free stainless steel.

Experiments were conducted in a specially designed reaction vessel using varying amounts of chromite, pyrolusite and aluminium powder to obtain a Fe-Cr-Mn alloy free from aluminium. It was observed that the reaction was very smooth and easy to control when an alloy containing 30 to 35 per cent manganese and 50 to 55 per cent chromium was obtained. Further work to study the effect of particle size of the reactants and flux additions is in progress.

35.0 Reducibility of Salem Magnetite Ore

The Salem magnetite deposits contain 30 to 35 per cent iron and about 45 per cent silica, and to assess the suitability of these deposits, reducibility tests were carried out on the concentrates obtained after the removal of silica by magnetic separation and tabling, with hydrogen as reducing agent at various temperatures and gas velocities.

Initially reducibility tests conducted on specially prepared cubical samples of lumped ore with hydrogen reducing agent at various temperatures and gas velocities showed that even though temperature and gas velocity were increased, the reducibility never exceeded 70 per cent after prolonged reduction for 2 hr. Reducibility tests carried out on briquettes from wet magnetic concentrates indicated that temperature higher than 800°C. accelerates the reducibility. In the different concentrates, reducibility of 90 per cent and above was obtained after reduction for 70 min. and this reducibility compares well with high grade haematite iron ores.

36.0 Thermal Beneficiation of Low-grade Chrome Ore for the Production of Ferro-chrome

The large reserve of low-grade Indian chromites having Cr : Fe ratio less than 3 cannot be directly used for the production of high-grade ferrochrome. The conventional ore-dressing methods failed to improve this ratio as FeO and Cr_2O_3 are chemically bound in the chrome-spinel. Attempts are being made to upgrade the ore by preferential reduction of FeO and its subsequent removal by acid leaching.

Experiments were carried with low-grade chromite from Mysore having Cr : Fe ratio of 1·72. Th [illegible] could be obtained at 1100° and 1150°C. using a reduction period of 2 and 1 hr. respectively, but the Cr recovery fell to about 43 and 53 per cent respectively. From a consideration of Cr : Fe ratio and Cr recovery, a temperature of 1100°C. and a period of 1 hr. were found to be optimum.

36.1 Thermal Beneficiation of Low-grade Ferruginous Manganese Ores for the Production of Ferro-manganese

The ferruginous manganese ores are not suitable for the production of standard grade ferro-manganese and could be upgraded by preferential reduction of iron producing a manganese rich slag. The iron obtained in the metallic form would be a useful byproduct.

Investigations were taken up with an ore from Koraput, Orissa, assaying Mn 39·9, Fe 10·9, SiO_2 7·8, Al_2O_3 4·5 and P 0·35 per cent. Preliminary experiments conducted with varying amounts of lamp black as reducing agent and with different smelting periods in graphite crucibles showed that high manganese slag assaying 50·6 per cent Mn having Mn : Fe ratio of 23·6 with a recovery of about 90 per cent Mn could be obtained by smelting the ore with carbon only at 1350°C. for 3 hr. Further experiments conducted with varying amounts of coke powder showed that under the optimum conditions of temperatures and time the amount of coke used did not materially influence the grade and recovery.

37.0 Development of Low-alloy High-strength Structural Steel

This is a very broad-based investigation, which has been taken up with the object of developing suitable low-alloy structural steels possessing good mechanical properties, working characteristics and weldability. A considerable amount of experimental work on this subject is being carried out by many the work proposed to be carried out in this laboratory will generally be with an emphasis on the utilization of indigenously available raw materials and elimination of materials imported from abroad to as great an extent as possible.

Several steel melts were prepared using both the high-frequency as well as the small electric arc furnace and after suitable homogenization, forging, rolling, etc., the mechanical properties of the steels have been determined. Further work is in progress.

38.0 Cladding of Stainless Steel on Mild Steel

Work was taken up with a view to develop a process for the cladding of mild steel with conventional 18 : 8 and other types of stainless steel, which can be used with advantage for a number of purposes in place of standard stainless steel. The process generally followed for cladding mild steel is the 'sandwich' process where two stainless steel plates are sandwiched between two mild steel plates of the requisite thickness. The stainless plates are separated by a suitable material which permits easy separation of the clad sheets after rolling. This process was adopted and a suitable 'sandwich' was hot-rolled from 1150°C. to the final required size. The clad steels have been found to possess good ductility and deep drawing characteristics. The bond strength between mild steel and stainless steel appears to be quite high as judged from the examination of the fracture obtained in the cupping test as well as from metallographic observation.

38.1 Cladding of Aluminium on Mild Steel

This is an investigation very similar to the above one, and has been carried out on more or less similar lines. The block was rolled at about 500°-550°C. to the requisite final thickness, with necessary reheating operations during rolling. The final composite sheet was annealed at 600°C. for about 3 hr. Both the cupping test as well as metallographic examination clearly indicated very good bond strength between aluminium and steel. The ductility and deep drawing capacity and surface finish of this sheet appeared to be better than those obtained by hot dipping or other methods of aluminizing.

39.0 Development of Controlled Friction Material

This investigation was taken up at the instance of the Railway Board to develop friction materials having a coefficient of friction not exceeding about 0·16. A special apparatus was designed and fabricated for this work.

During the year under review, further modifications were carried out on the fabric liner by drilling small holes through its surface which considerably increased the soaking surface of the fabric liner. With grey cast iron, it gave a coefficient of friction, not exceeding 0·15 for even 200,000 to-and-fro motions, at a pressure of 300 lb./sq. in. It may be noted in this connection that the coefficient of friction between a fabric liner and phosphor-bronze, as at present used by the Indian Railways, was found to exceed about 0·3 after about 1600 to-and-fro motions.

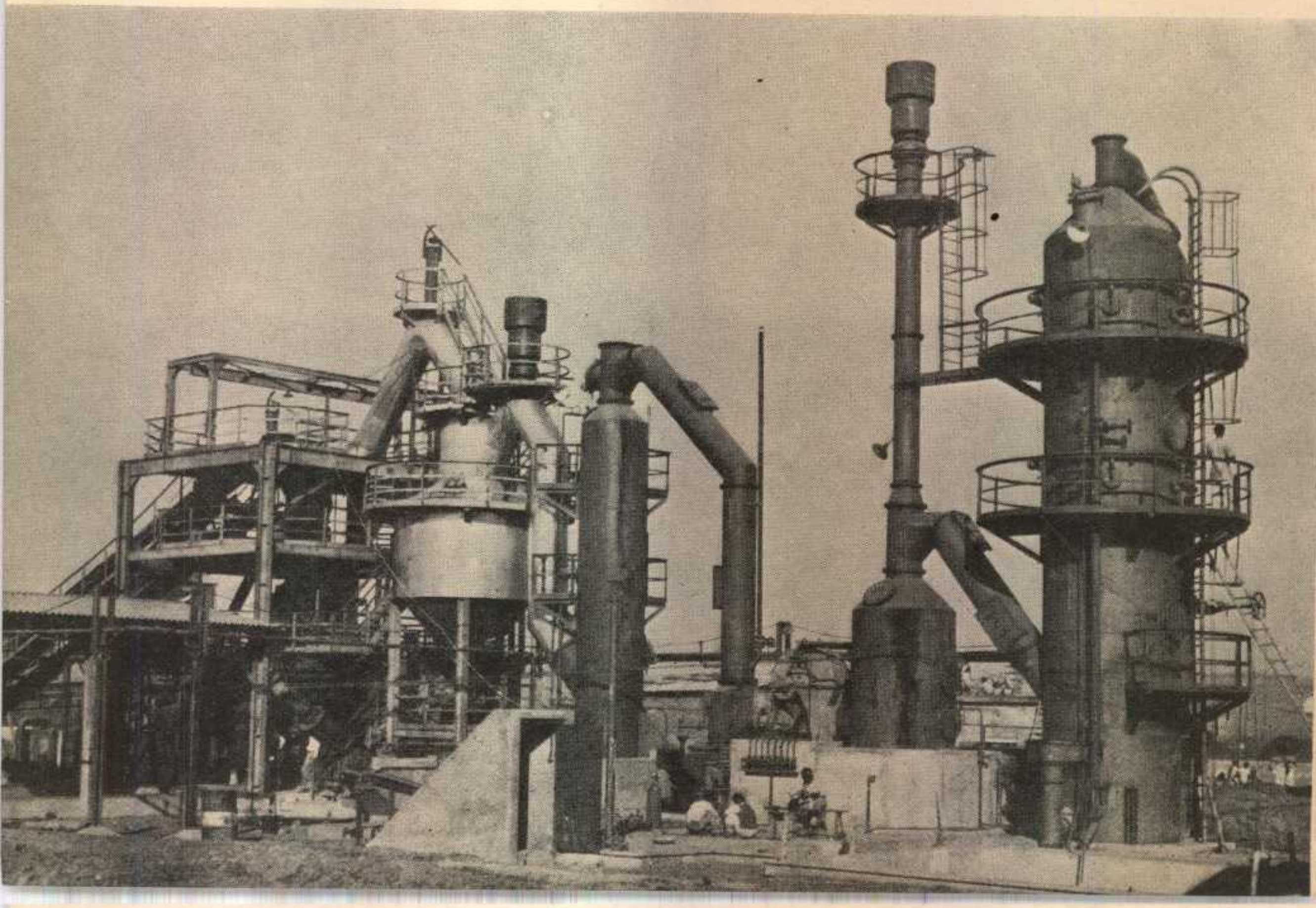
PILOT PLANTS

40.0 Low-shaft Furnace Project

This project has been initiated to obtain primarily commercial grades of pig iron from fine grained or soft haematite iron ores, or other low-grade iron ores employing non-coking coals, coke-breeze or other solid fuels like carbonized lignite which are unsuitable for smelting in conventional blast furnace. The utilization of Salem magnetite is also kept in view and it is proposed to study the effects of the mode of burden preparation, charging of the raw materials in lumpy form in layers, blast temperature, pressure and volume on the smelting operation to arrive at the optimum conditions. The effect of oxygen enrichment of the blast and controlled humidity on the furnace performance will also be determined as and when such facilities become available. Production of standard grade of ferro-manganese from indigenous raw materials is also envisaged.

The State Government of Bombay and Madras are interested to test the suitability of smelting iron ores and non-coking coals in this pilot furnace with a view to instal a commercial low-shaft furnace in their respective States. Certain countries of the ECAFE region are also evincing interest in this project for undertaking investigations on their behalf basing on their raw materials.

A VIEW OF THE 15 TONS/DAY PILOT LOW-SHAFT FURNACE PLANT FOR MAKING PIG IRON

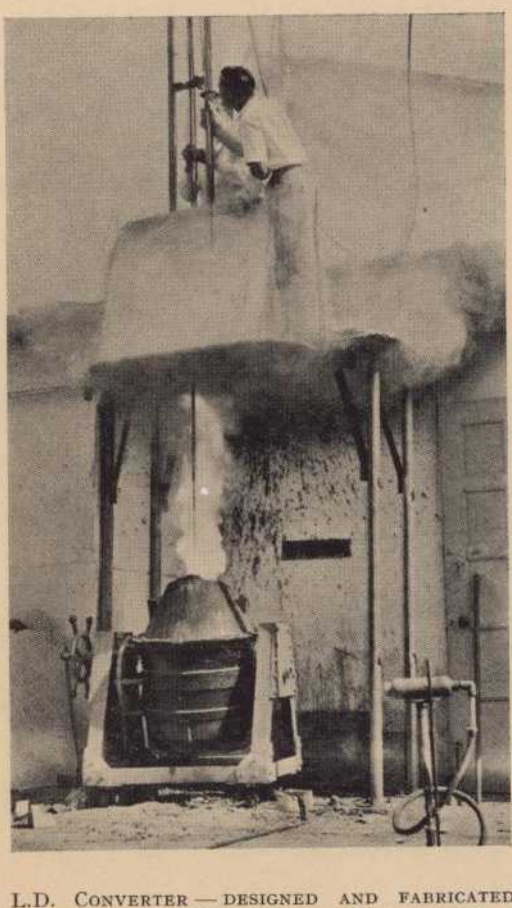


The construction work for the installation of the furnace and auxilliary plants is now in progress and the furnace is expected to go into production during the current year.

41.0 Pilot Plant Production of Steel by L.D. Process

Pilot plant studies on the production of steel by the L.D. process has been undertaken in this laboratory with a view to collect data which will be helpful in the country's steel expansion programme.

A basic lined L.D. converter having a capacity of treating 0·1 ton of molten metal per blow has been designed and fabricated in this laboratory for conducting the experiments. The converter was 'blown' a number of times with oxygen lancing under high pressure. The removal of metalloids was very effective, and encouraging results have been obtained.



L.D. CONVERTER — DESIGNED AND FABRICATED AT THE NATIONAL METALLURGICAL LABORATORY — IN OPERATION

The technique for the production of low-phosphorus, low-carbon steel from Indian pig iron was greatly improved upon by adopting a double slagging process with the addition of mill scale and iron ore as cooling agent. Lancing was made for a period of about 10½ minutes with an oxygen pressure of 120 lb./sq. in. and the following results were obtained.

	Pig Iron %	*Steel Produced* %
C	3·2	0·02
P	0·39	0·035
Si	1·36	0·019
Mn	0·79	0·09
S	0·039	0·03

Pilot plant investigations on this process are continuing at the National Metallurgical Laboratory and are expected to yield valuable data not only on the properties of Indian pig irons but also on the suitability and performance of India-made basic refractories for use in oxygen steel converters.

42.0 Hot-dip Aluminizing of Steel Wire and Sheets

The design of the pilot plant for aluminizing steel wire and sheets has been completed and fabrication job is underway. Work has also been taken up on aluminizing of a number of materials like channels, angles, loop nuts, etc., received from Post & Telegraphs Workshop by the National Metallurgical Laboratory patented process. Component parts of automobile mufflers like passage tube, end covers and shells received from Messrs Premier Automobiles have been aluminized and will be shortly sent for practical trial and report.

43.0 Refractories Pilot Plant

A number of research projects on refrac-
pilot plant trials are awaiting the construc-
tion of the bay and erection of the equipment. Except for a very few special items, it is proposed to buy other pilot plant equipment from dealers in this country or fabricate in the laboratory itself.

Semi-pilot plant trials of some of the products have been pursued actively with the very limited size of experimental equipment available in the laboratory at present and making suitable improvisations wherever possible. Noteworthy among such are carbon and clay-bonded graphite crucible, carbon refractories, insulation refractories from bladed kyanite, etc.

44.0 Concentration of Ferruginous Manganese Ores

Semi-pilot plant trials based on low-temperature magnetizing reduction process and reduction roast followed by magnetic separation have been conducted on ferruginous manganese ores from Keonjhar Dist. Procurement and fabrication of the necessary equipment are underway for the erection of a pilot plant with a capacity $\frac{3}{4}$ to 1 ton of ore per hour for treating low-grade manganese, chrome and other ores. The bay for housing the plant is under construction.

45.0 Thermal Beneficiation of Low-grade Manganese and Chromite Ores

Design, fabrication and procurement of equipment for the installation of pilot plant for conducting work on thermal beneficiation of low-grade manganese and chromite ore are being taken up and the bay for housing the plant is under construction.

46.0 Chemical Polishing of Aluminium

Semi-pilot plant trials were undertaken on the chemical polishing of aluminium using the patented compositions developed in this laboratory. It was found that with suitable adjustment of the composition and with good polishing could be obtained. The patented process has now been released to interested parties free of royalty.

47.0 Electrolytic Manganese

Substantial progress has been made on the production of electrolytic manganese on a semi-pilot plant scale. The cells are under continuous operation producing 32 lb. of metal per day. With the development of nickel-free austenitic stainless steel and nickel-free coinage alloys, in which nickel is replaced by electrolytic manganese, the potential demand for this metal has greatly increased. The cost of the electrolytic manganese produced by the N.M.L. patented process has been estimated to be between Rs. 1500 and Rs. 2000 per ton. Arrangements are being made for increasing the capacity of the plant to 100 lb./day.

48.0 Electrolytic Manganese Dioxide

Work on the semi-pilot plant production of electrolytic manganese dioxide of 99·99 per cent purity by N.M.L. patented process is being continued and the capacity of the plant will be shortly increased to 100 lb./day. Samples have been sent to some leading manufacturers of dry batteries for service trials.

It is understood that out of 5500 tons of electrolytic manganese dioxide imported in the country, about 4000 tons are consumed by dry battery manufacturers. With the rapid development of dry battery industries, it is expected that there will be great demand for this material in the near future and successful exploitation of this process can effect a considerable saving in foreign exchange.

LIAISON AND INFORMATION SERVICES

Valuable technical and statistical data useful to the different research projects have been compiled. A resumé comprising the titles of technical research papers published in various journals was initiated for the benefit of the research workers; thirty-three technical reports were prepared and circulated to those interested; technical advice was tendered on a variety of subjects to Government organizations, industries and a large number of private parties. Twenty-eight papers were published in various technical journals and seven patents were filed. Special brochures were prepared on important occasions and press conferences were arranged to disseminate the results of research.

TECHNICAL AID TO INDUSTRIES

To solve the problems faced by the country's metallurgical and allied industries and to aid in their development, technical advice was tendered to various industrial organizations and Government bodies. 127 technical enquiries were attended and forty-five short-term investigation and specification tests on behalf of the industries were conducted during the period under review.

PATENTS

Non-technical Notes

During the year under review, non-technical notes on the following patented processes were prepared and circulated:

1. An improved process for the production of electrolytic manganese metal — Patent No. 49355.
2. An improved process for electrolytic production of high purity manganese dioxide — Patent No. 47982.
3. Improvement in or relating to the electroplating of metals on aluminium or its alloys — Patent No. 51524.
4. Improvement in or relating to metallization of non-conductors — Patent No. 45579.
5. Chemical Polishing of Aluminium — Patent No. 47401.
6. Refractory composition consisting graphite and silicon carbide and improvements thereon — Patent No. 58869.

Great interest has been shown by a large number of industries for the commercial exploitation of the above processes and concrete offers for the commercial exploitation of the patents have been received which are under consideration.

Patents filed

The following patents have been filed during the period under review:

1. Nickel-free chromium-manganese-nitrogen stainless steels, Type I — Patent No. 61978, dated 12 October 1957.
2. Nickel-free chromium-manganese-nitrogen stainless steel, Type II — Patent No. 61979, dated 12 October 1957.
3. Nickel-free chromium-manganese-nitrogen stainless steel, Type III — Patent No. 61980, dated 12 October 1957.
4. A process for the stabilization of dolomite and a method of making refractory bricks from stabilized dolomite — Patent No. 61981, dated 12 October 1957.
5. An improved method for producing nitrided manganese — Patent No. 61338, dated 21 November 1957.
6. Refractory compositions comprising graphite and alumino-silicate materials and glazes to render such compositions resistant to oxidation — Patent No. 62352, dated 22 November 1957.
7. A process to produce carbon aggregates from carbonaceous materials of varied volatile contents — Patent No. 62938, dated 25 January 1958.

PRACTICAL DEMONSTRATION

Proposals for short-term training programmes in some of the important processes developed in this laboratory have been finalized to implement the decision arrived at between the C.S.I.R. and Ministry of Community Development.

To start with, it is proposed to arrange for a training programme for two representatives from Small-scale Industries Service Institute, in the subject of electroplating on which this laboratory has done pioneering work.

Besides, a ten-day demonstration programme is being arranged for imparting working knowledge of the following patents which have been released free of royalties for the benefit of the small plating industries:

(i) Electroplating on aluminium,
(ii) Metallization of non-conductors,
(iii) Brass plating from non-cyanide bath,
(iv) Chemical polishing of aluminium.

The process will be demonstrated to the industries in near future and it is hoped that they will go for early commercial exploitation of the methods and justify the purpose for which these patents have been released free of royalties.

SYMPOSIA AND COLLOQUIA

A symposium on " Recent Developments in Foundry Technology " was held from 5 to 8 February 1958 under the auspices of the National Metallurgical Laboratory and the Institute of Indian Foundry Men.

This symposium helped a great deal to focus on the latest developments in foundry technology and to study scientific developments abroad in the techniques of founding metals and alloys which could be successfully implemented in the Indian foundry industry.

A foundry exhibition, first of its kind in India, was organized under the joint auspices of the National Metallurgical Laboratory and the Institute of Indian Foundry Men. The exhibition was formally opened by Prof. M. S. Thacker, Director-General, Scientific & Industrial Research. All the leading foundry men in India took part in the exhibition which symbolized the growth and development of the foundry industry, catering to various spheres of production. The exhibition drew a large attendance and

PROF. M. S. THACKER, DIRECTOR-GENERAL, SCIENTIFIC & INDUSTRIAL RESEARCH, DELIVERING THE INAUGURAL ADDRESS AT THE SYMPOSIUM ON " RECENT DEVELOPMENT IN FOUNDRY TECHNOLOGY " all the delegates, who participated in the Foundry Symposium took keen interest in cularly were very much impressed with the

exhibits and many had constructive comments to offer on the items displayed sub-jects during the year:

Subject	*Speaker*
1. Effect of Specimen Size on the Precipitation hardening, Quenched and Quench-aged Al-4 per cent Copper Alloy of High Purity	Shri Ved Prakash
2. Statistical Research Methods and Their Applications in Operational Research in Metallurgical Production Plants	Shri K. N. Srivastava
3. Gas Analysis in Steel by Vacuum Fusion Method	Shri N. G. Banerjee
4. Radio-active Tracer Technique in Flotation Research	Shri G. V. Subramanya Iyer
5. Developments in Oxygen Steel-making Process	Dr. A. B. Chatterjea
6. Friction and Frictional Materials	Shri B. N. Das
7. Thermogravimetric Studies in the Oxidation of Some Natural Graphite	Shri H. P. S. Murthy
8. The Lattice-parameters of Iron-chromium Alloys	Shri L. J. Balasundaram
9. Carbides in Low-alloy Steel	Shri J. K. Mukherjee
10. Developments in Copper Extraction Metallurgy	Shri P. K. Gupta
11. Simultaneous Determination of Copper Aluminium and Magnesium in Zinc Alloys for Die-casting by the Cup-spark Technique	Shri M. K. Gupta
12. Metallurgical Materials and Problems in the Construction of Nuclear Reactors	Dr. B. C. Kar
13. Microscopic Techniques in Mineral Dressing	Shri P. Dharma Rao
14. Foundry Industry in U.K. and Recent Developments in Foundry Technology	Shri R. M. Krishnan
15. Certain Phase Relationship in the System MgO-Fe_2O_3-TiO_2-SiO_2	Shri M. R. K. Rao
16. Wear of Railway Materials	Shri R. Choubey
17. Alumino-thermic Reduction of Titanium Dioxide	Shri R. A. Sharma
18. Stainless Steel	Shri S. S. Bhatnagar
19. Electrolytic Production of Zirconium Dioxide	Shri P. B. Chakrabarty
20. Aluminizing of Steel by Aqueous Flux Process	Shri S. M. Arora
21. Upgrading of Bikaner Gypsum and Salem Magnesites	Shri P. V. Raman
22. Comparative Studies of Foreign and Indigenous Silica Bricks	Shri Gurbux Singh
23. Deformation of Metals	Dr. E. G. Ramachandran

Subject	Speaker
24. Alloy Deposition	Shri Y. N. Sadana
25. Textural Structure of Cold Rolled Aluminium	Shri K. D. Maji
26. Core Hardening by CO_2 Process	Shri B. V. Somayajulu
27. A Study of Shevaroy Bauxite for the Development of High Alumina Refractory	Shri H. V. Bhaskar Rao
28. The Utilization of Domestic Chrome Ores for the Production of Ferro-chromium	Shri M. C. Sen
29. Significance of Micrographic Studies in Ore-dressing	Shri M. S. Chopra

49.0 Distinguished Visitors

During the period under review, distinguished visitors like Prime Minister, Shri Jawaharlal Nehru, Dr. Zakir Hussain, Governor of Bihar, Academician I. P. Bardin, Vice-President, U.S.S.R. Academy of Science, Sardar Swaran Singh and Shri Morarji Desai, Cabinet Ministers, Government of India, Mr. J. R. D. Tata, Chairman, Tata Industries Ltd., Sir J. J. Ghandy, Chairman, Executive Council of National Metallurgical Laboratory, etc., besides many other renowned Indian and foreign visitors visited the laboratory.

AWARDS, DEPUTATIONS AND NOMINATIONS

Awards

Dr. B. R. Nijhawan, Director, has been awarded 'Padma Shri' by the President of India on the Republic Day 26th January 1958.

Deputations

1. Dr. B. R. Nijhawan was deputed to attend the Second World Metallurgical Congress held at Chicago, U.S.A., during October-November 1957. During his deputation, Dr. Nijhawan visited a number of research and industrial organizations in U.S.A. and U.K.

2. Shri B. N. Das, Senior Scientific Officer, has been deputed to undergo training in Industrial Metallurgy under the Technical co-operation Scheme of Colombo Plan in the U.K.

Nominations

Dr. B. R. Nijhawan, Director, National Metallurgical Laboratory, has been appointed as a Director of Messrs Hindusthan Cables (Private) Ltd., Rupnarainpur, District Burdwan, West Bengal, with effect from 15 May 1957.

Dr. B. R. Nijhawan has been nominated:

(i) On the All-India Board for technical study in Engineering and Metallurgy as representative of the Co-ordinating Committee of the All-India Council for Technical Education for a period of 3 years with effect from 1 January 1957.

(ii) To act as a Member of the Standing Advisory Committee for the department of Metallurgy of the Indian Institute of Science, Bangalore.

(iii) To serve as Member of the Expert Committee on Metallurgical Engineering appointed by the All-India Board of Technical Studies in Engineering and Metallurgy.

Dr. T. Banerjee, Deputy Director, has been nominated as:

(i) Chairman of the Electroplating Sectional Committee ETDC 12.

(ii) Representative of C.S.I.R. on the Panel for Corrosion Research of Light Gauge Steel Structures SMDC 1/P3.

(iii) Member of the Engineering Hardware and Equipment Sectional Committee EDC-32 of the Indian Standards Institution.

Dr. E. G. Ramchandran, Assistant Director, has been nominated as a Member of Structural Steel Sectional Committee (BD 7) (Steel Economy) of Indian Standards Institution.

Shri R. M. Krishnan, Senior Scientific Officer, has been nominated as Member and Convener on the Panel on Sampling of Foundry Sand SMDC 4/P3 of Indian Standards Institution.

Shri H. V. Bhaskar Rao, Senior Scientific Officer, has been nominated as a representative of C.S.I.R. on the Panel for classification of Clays for Ceramic Industry SMDC 18/PL of the Refractories Sectional Committee, SMDC 18 of Indian Standards Institution.

Shri K. N. Srivastava, Senior Scientific Officer, has been elected as an Associated Member of the Institution of Metallurgists, London.

APPENDIX I

PUBLICATIONS

Proceedings of the following symposia organized by the National Metallurgical Laboratory were published during the period under review as mentioned below:

(i) Industrial Failure of Engineering Metals and Alloys.

(ii) Non-ferrous Metal Industry in India.

(iii) Recent Trends in the Field of Production, Practice and Research on Refractories in Metal Industries.

(iv) Production, Properties and Application of Alloy and Special Steels.

Besides the above, the following papers and articles were published in leading Indian and foreign Scientific journals.

A — Original Publications

1. BHASKAR RAO, H. V. & RABINDAR SINGH, " A Comparative Study of Indian and Foreign Silica Bricks ", *J. sci. industr. Res.*, **16A,** (1957), 183-88.
2. BHATNAGAR, P. P. & SHARMA, R. A., " Studies on the Preparation of Titanium Tetra-Iodide ", *J. & Proc. Inst. Chem.*, **29,** Pt. II, 97-105.
3. SHARMA, R. A., BHATNAGAR, P. P. & BANERJEE, T., " Separation of Nickel and Zinc from a Mixture of Their Salts: Pt. II — Reduction of Nickel Oxide ", *J. sci. industr. Res.*, **16A,** (1957), 255-59.
4. NARAYANAN, M. A. & NARAYANAN, P. I. A., " Beneficiation of Low Grade Fluorspar from Chandidongri Mines, Drug (M.P.) ", *J. sci. industr. Res.*, **16A,** (1957), 260-65.
5. SOMAYAJULU, B. V. & NIJHAWAN, B. R., " Bonding Characteristics of Rajasthan Bentonite ", *J. sci. industr. Res.*, **17A,** (1957), 265-68.
6. SHARMA, U. C. & NIJHAWAN, B. R., " Moulding Characteristics of Jabbalpur Pale Grey Sand ", *J. sci. industr. Res.*, **16A,** (1957), 424-27.
7. RAMAKRISHNA RAO, M., " Melting Points and Certain Phase Relationships in the System Magnesium Orthosilicate, Magnesium Orthotitanate, Magnesioferrite ", *J. sci. industr. Res.*, **16B,** (1957), 444-51.
8. GOSWAMI, J., CHATTERJEA, A. B. & NIJHAWAN, B. R., " Use of Fusite in Desulphurizing Off Grade Pig Iron ", *J. sci. industr. Res.*, **16A,** (1957), 522-26.
9. KRISHNAN, R. M. & NIJHAWAN, B. R., " Moulding Characteristics of Allahabad Sand ", *J. sci. industr. Res.*, **16A,** (1957), 517-21.
10. SOMAYAJULU, B. V. & NIJHAWAN, B. R., " Moulding Characteristics of Hardwar Sand ", *J. sci. industr. Res.*, **16A,** (1957), 566-70.
11. RAMKRISHNA RAO, M., MOORTHY, V. K. & RABINDER SINGH, " Production of Forsterite Refractories Using Serpentine and Dunite as Raw Materials: Pt. I — Development of

Suitable Refractory Composition using Serpentine and Dunite as Raw Materials"

12. GUPTE, P. K., BHATNAGAR, S. S. & NIJHAWAN, B. R., " Phosphorus Dilution of Iron in Small Experimental Cupola ", *Transactions of the Indian Institute of Metals*, (1956-57), 61-72.
13. MOHAN, J., GUPTE, P. K. & NIJHAWAN, B. R., " Direct Reduction of Iron Ore to Yield Usable Steel, *Transactions of the Indian Institute of Metals*, (1956-57), 73-81.
14. DAS, B. N. & SANI, G. D., " Impact Fatigue Resistance of Structural Steels ", *Transactions of the Indian Institute of Metals*, (1956-57), 103-18.
15. SHARMA, R. A., KAPOOR, A. N. & CHATTERJEA, A. B., " Preparation of Ti-Al Alloys by Alumino-Thermic Reduction: Pt. I — Modified Alumino-Thermic ", *Transactions of the Indian Institute of Metals*, (1956-57), 169-80.
16. RABINDAR SINGH, MOORTHY, V. K. & SEN, P. C., " Improvements of the Properties of Forsterite Refractories ", *Bull. Soc. Franc. Ceram.*, **35**, (1957), 21-33.

B — Review Articles

1. CHATTERJEA, A. B., " Economy of Alloying Elements in Steels ", *The Eastern Metals Review*, **10**, (1957), 395-97.
2. NIJHAWAN, B. R., " Austenitic Stainless Steels ", *The Eastern Metals Review*, **11**, (1958), 246.
3. BANERJEE, T., " Large Scale Production of Electrolytic Manganese and Manganese Dioxide from Low Grade Indian Manganese Ores ", *India in Industries* [Published by Indian Market Research Bureau (Sept. 1957)], General Section, 1-9.
4. NIJHAWAN, B. R., " Ferromanganese from Lean Ore ", *Metal Progress*, **73**, (1958), 112-16.
5. NARAYANAN, P. I. A., " Development of Ore-dressing in India ", *Golden Jubilee Commemoration Volume of the Mining, Geological & Metallurgical Institute of India* (1906-55), 398-404.
6. BANERJEE T., " Physico-Chemical Principles ", *TISCO Review*, **4**, (1957), 101-108.
7. CHATTERJEA, A. B., " Reactions of Phosphorus ", *TISCO Review*, **4**, (1957), 146-153.
8. RANGANATHAN, S., " Moulding of Machine Parts from Metal Powders ", *Annual Number of the Eastern Metals Review*, **10**, (1957), 103-106.
9. BANERJEE T. & LAHIRI, A. K., " Cylinder liner Wear in Internal Combustion Engine ", *The Eastern Metals Review*, **11**, (1958), 267-268.
10. CHATTERJEA, A. B., " Production of Steel by Use of Oxygen ", *Annual Number of the Eastern Metals Review*, **10**, (1957), 87-88.

Letters to the Editor

1. DAS GUPTA, S. B. & NARAYANAN, P. I. A., " Beneficiation of a Lateritic Iron Ore from Rajharapahar (M.P.) ", *J. sci. industr. Res.*, **16A**, (1957), 373.
2. DAS GUPTA, S. B. & NARAYANAN, P. I. A., " Recovery of Sulphur and Gold from Tailing of Nundy Droog Mines, Kolar Gold Fields ", *J. sci. industr. Res.*, **16A**, (1957), 374.

APPENDIX II

RESEARCH AND INVESTIGATION REPORTS PREPARED DURING THE PERIOD UNDER REVIEW

1. An Investigation on Sintering and Semi-stabilization of Dolomite for Bhilai Steel Plant — M. Ramakrishnan Rao, P. C. Sen, N. V. Naidu & H. V. Bhaskar Rao (IR.105/57)
2. Dressing of a Low Grade Iron Ore from Badampahar — N. N. Subramanian & P. I. A. Narayanan (IR.106/57)
3. Beneficiation of Gypsum Samples from Jamsar Mines, Rajasthan — P. V. Raman & P. I. A. Narayanan (IR.107/57)
4. Uranium Recovery from the I.C.C. Tailings by Tabling and Magnetic Separation Method — G. P. Mathur & P. I. A. Narayanan (IR.108/57)
5. Preliminary Report on the Possibility of Beneficiating a Sand Sample from the Associated Cement Companies Ltd. — P. I. A. Narayanan & M. S. Chopra (IR.109/57)
6. Reduction of Silica Content in a Magnesite Sample from Salem — P. Dharma Rao, P. V. Raman & P. I. A. Narayanan (IR.110/57)
7. Beneficiation of Kyanite from Badia, Bihar — S. B. Das Gupta, P. V. Raman & P. I. A. Narayanan (IR.111/57)
8. Beneficiation of a Low Grade Manganese Ore from Sambalpur, Orissa—K. Satyanarayana G. V. Subramanya & P. I. A. Narayanan (IR.112/57)
9. Beneficiation of Low Grade Manganese Ore from Chitaldrug, Mysore — G. P. Mathur & P. I. A. Narayanan (IR.113/57)
10. Beneficiation of Low Grade Manganese Ore from Kodur Mine Dumps, Andhra — G. V. Subramanya, B. L. Sen Gupta & P. I. A. Narayanan (IR.114/57)
11. Beneficiation of Low Grade Kyanite from Singhpura, Bihar — S. K. Banerjee, K. Satya-narayana & P. I. A. Narayanan (IR.115/57)
12. Beneficiation of Low Grade Magnetite from Salem, Madras: Part I — S. K. Banerjee & P. I. A. Narayanan (IR.116/58)
13. Beneficiation of Low Grade Manganese Ore from Kuttinga, Koraput District, Orissa — B. L. Sen Gupta, G. V. Subramanya & P. I. A. Narayanan (IR.117/58)
14. Investigation on Usha Industrial Sewing Machine (Type 31-K-15 No. A. 1251) and Singer Industrial Sewing Machine (Top Model 31-K-15, No. EJ86662) (IR.118/58)
15. Beneficiation of Iron Ore Sample from Bonai, Orissa — G. P. Mathur, B. L. Sen Gupta & P. I. A. Narayanan (IR.119/58)
16. Moulding Characteristics of Oyaria Sand — Santokh Singh, B. V. Somayajulu & B. R. Nijhawan (IR.120/58)
17. Reducibility of Salem Magnetite Ore — M. Subramaniam & P. P. Bhatnagar (IR.121/58)

18. Data on Indigenous Foundry Sands and Bonding Clays (RR.86/57)
19. An Improved Method for the Simultaneous Determination of Aluminium Copper and Magnesium in Zinc Alloys by Spectrographic Method — B. C. Kar, M. K. Gupta & V. Muthukrishnan (RR.87/57)
20. Aluminising of Steels by the Aqueous Flux Process — S. M. Arora, P. K. Gupte & B. R. Nijhawan (RR.88/57)
21. Thermogravimetric Study of the Oxidation of Some Natural Graphites — T. V. Prasad, H. P. S. Murthy, H. V. Bhaskar Rao & Rabindar Singh (RR 89/57)
22. Spectrochemical Analysis of Aluminium Alloys by the Oxide Ore Technique — M. K. Gupta & B. C. Kar (RR.90/57)
23. Improvement of Certain Indian Refractory Clays by *p*H Control — H. P. S. Murthy & M. R. K. Murthy (RR.91/57)
24. Preparation of Titanium — Aluminium Alloys by Alumino-thermic Reduction: Part II — by Use of Energisers — R. A. Sharma, A. N. Kapoor & A. B. Chatterjea (RR.92/57)
25. Studies on Indian Refractory Clays: Part I — Clays from Madhya Pradesh Area — T. V. Prasad & H. P. S. Murthy (RR.93/57)
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8. Tempering of Steel — A. B. Chatterjea (LR.51/58)